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AN ANALYSIS OF COMPOSITE DRIVE SHAFT USING ANSYS ACP

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ABSTRACT

Almost all automobiles (at least those which correspond to design with a rear wheel drive and front engine installation) have transmission shafts. The weight reduction of the drive shaft can have a certain role in the general weight reduction of the vehicle and is a highly desirable goal, if it can be achieved without an increase in the cost and decrease in the quality and reliability.

In this paper, an automobile drive shaft is designed using ANSYS ACP workbench and analysis performed using ANSYS static structural workbench. Analysis preformed on 4 different materials which includes conventional structural steel and 3 different composite materials. E glass/ Epoxy, High strength Carbon Epoxy (230GPA) and High Modulus Carbon Epoxy (395GPA). Results are compared and conclude High strength carbon is the optimum material for manufacturing the automobile drive shaft.

KEYWORDS: Driving Shaft, Composite Material & ANSYS ACP

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Original Article

INTRODUCTION

A driveshaft is a rotating shaft that transmits drive to the wheels. Drive shaft must operate through constantly changing angles between the transmission and axle. High quality steel (Steel SM45) is a common material for construction. Steel drive shafts are usually manufactured in two pieces to increase the fundamental bending natural frequency because the bending natural frequency of a shaft is inversely Proportional to the square of beam length and Proportional to the square root of specific modulus.

This work deals with the analysis of conventional steel shaft and 3 different composite shafts. Results proves that how beneficial is the replacement of a conventional steel drive shaft with E-Glass/ Epoxy High strength carbon/epoxy and High modulus carbon /epoxy composite drive shafts for an automobile application. This present work an attempt has been to estimate the deflection, stresses and natural frequencies under subjected loads using ANSYS ACP. A further comparison carried out for both conventional and composite shafts.

DRIVE SHAFT COMPARISON

Demerits of Conventional Drive Shaft

- They have less specific modulus and strength.
- Weight is high compared to composites.

- Manufactured in Two pieces due to bending natural frequency.
- Corrosion resistance less
- Steel drive shafts have less damping capacity.

Merits of Composite Drive Shafts

- They have high specific modulus and strength.
- Weight is less compared to conventional drive shafts.
- The fundamental natural frequency of the carbon fiber composite drive shaft can be twice as high as that of steel.
- They have a high damping capacity hence they produce less vibration and noise.
- They have good corrosion resistance
- Introduction to ANSYS Composite Prep Post (ACP)
- ANSYS Composite Prep Post training is geared towards engineers who are designing and analyzing layered composites.
- Adding Composites Definitions to Assemblies
- Modelling Composite Stacking's and Orientations
- Understanding Product Performance
- Toward Manufacturing
- 3-D Models for Thick Composites

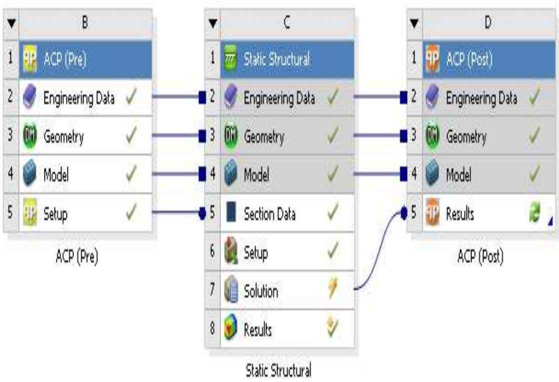

Figure 1: ANSYS ACP

Table 1: Specification of Drive shaft

Parameter of the Shaft	Symbol	Value	Unit
Outer Diameter	D_O	90	mm
Inner Diameter	D_i	80	mm
Length of the Shaft	L	1200	mm
Thickness of the shaft	t	5	mm
Ultimate Torque	T max	3500	Nm
Max speed of shaft	N max	6500	rpm

Material Properties of Structural Steel

Name: Structural Steel

Model type: Linear Elastic Isotropic

Default failure criterion: Max von Misses Stress

Yield strength: 6.20422e+008 N/m^2

Tensile strength: 7.23826e+008 N/m^2

Elastic modulus: 2.1e+011 N/m^2Poisson's ratio: 0.28

Mass density: 7600 kg/m^3

Shear modulus: 7.9e+010 N/m^2

Thermal expansion coefficient: 1.3e-005 /Kelvin

Material Properties of Epoxy E-Glass

Name: Epoxy E-Glass Grade: G-10 Normalized To 60% Fibre Volume

Model Type: Orthotropic Elasticity

Default Failure Criterion: Max Von Misses

Density: 2000 Kg/M^3

Ply Type: Regular

Mesh Sizing: 10mm

No of Layers: 5

Stacking Sequence: 0-45-90-45-0

Table 2: Material Properties of Epoxy E-Glass

Property	X/XY	Y/YZ	Z/XZ	UNITS
Young`S Modulus	45000	10000	10000	Mpa
Possions Ratio	0.3	0.4	0.3	-
Shear Modulus	5000	3846.2	5000	Mpa
Tensile Stress	1100	35	35	Mpa
Compressive Stress	-675	-120	-120	Mpa
Shear Stress	80	46.154	80	Mpa

Material Properties of Epoxy Carbon 230 Gpa Prepeg

Name: High Strength Epoxy Carbon 230 Gpa Prepeg

Grade: T300 Normalized To 60% Fibre Volume

Model Type: Orthotropic Elasticity

Default Failure Criterion: Max Von Misses

Density: 1490 Kg/M^3

Ply Type: Regular

Mesh Sizing: 10mm

No of Layers: 5

Stacking Sequence: 0-45-90-45-0

Table 3: Material Properties of Epoxy Carbon 230 Gpa Prepeg

Property	X/XY	Y/YZ	Z/XZ	UNITS
Young`S Modulus	121000	8600	8600	Mpa
Possions Ratio	0.27	0.4	0.27	-
Shear Modulus	4700	3100	4700	Mpa
Tensile Stress	2231	29	29	Mpa
Compressive Stress	-1082	-100	-100	Mpa
Shear Stress	60	32	60	Mpa

Material Properties of Epoxy Carbon 395 Gpa Prepeg

Name: High Modulus Epoxy Carbon 395 Gpa Prepeg

Grade: M40j Normalized To 60% Fibre Volume

Model Type: Orthotropic Elasticity

Default Failure Criterion: Max Von Misses

Density: 1540 Kg/M^3

Ply Type: Regular

Mesh sizing: 10mm

No of Layers: 5

Stacking Sequence: 0-45-90-45-0

Table 4: Material Properties of Epoxy Carbon 395 Gpa Prepeg

Property	X/XY	Y/YZ	Z/XZ	UNITS
Young`S Modulus	209000	9450	9450	Mpa
Possions Ratio	0.27	0.4	0.27	-
Shear Modulus	5500	3900	5500	Mpa
Tensile Stress	1979	26	26	Mpa
Compressive Stress	-893	-139	-139	Mpa
Shear Stress	100	50	100	Mpa

Modelling In ACP

- Start ANSYS workbench and drag ACP (Pre) to project schematic.
- Select required material from engineering data.
- Enter into Geometry and design desired profile at 0 mm thickness.

- Next, open Model cell, assign material, 1mm thickness and complete mesh.

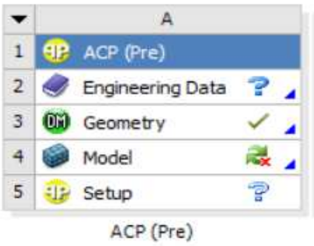

Figure 2: Modelling in ACP

- Open setup, select and create Fabrics under Material Data.
- Add new rosette to model and define a rosette type as parallel.
- Create new oriented element set using rosette and elements set as required.
- Create Ply Group with the help of oriented elements and enter an angle, no layers.
- Create Ply with different angles as required.
- Update the model and convert to a solid model.

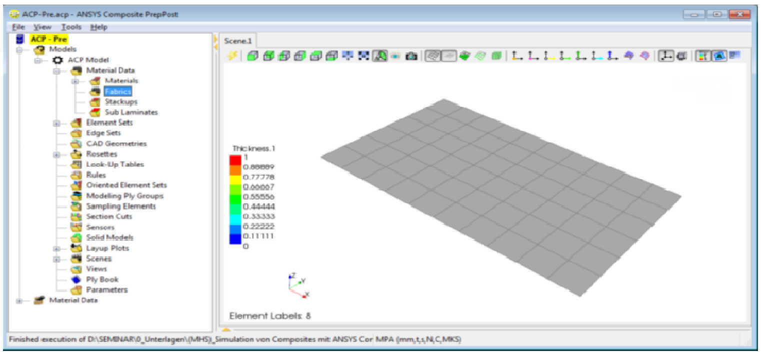

Figure 3: ACP workspace

- Drag and drop static structural workbench to project schematic and connect setup cell from ACP (Pre) to model cell in static structural, select option "transfer solid data".
- Open the model cell in static structural and Check the geometry.

Structural Analysis in ANSYS

- Open model cell in static structural and select static structural from model tree.
- Apply constraint on one end of the shaft.
- Apply Moment force of 3500N-m on the other end of the shaft.
- Select Total deformation, Von misses, shear strain from Solution option and execute the solution.
- At project schematic right click on solution cell from static structural and select "Transfer data" -> "Modal".
- Open modal workbench and select total deformation option from solution part.

- Execute the solution and evaluate the results.

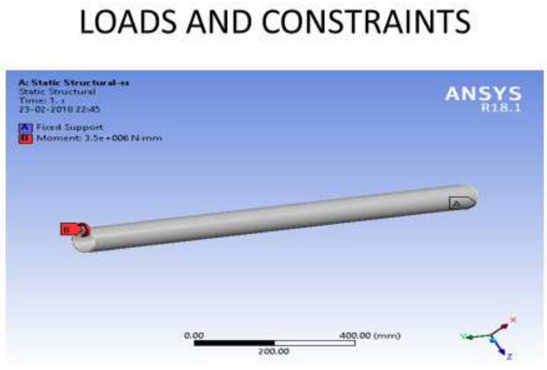

Figure 4: Loads and Constraints of Structural Steel

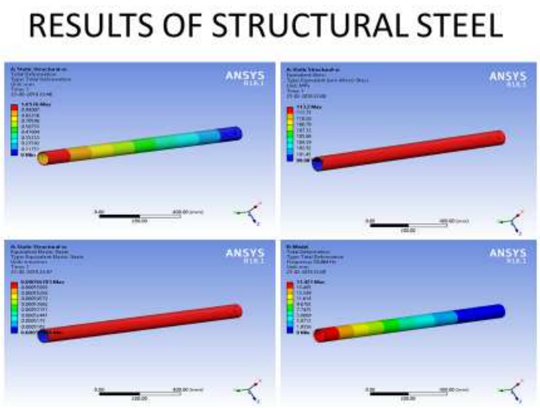

Figure 5: Results of Structural Steel

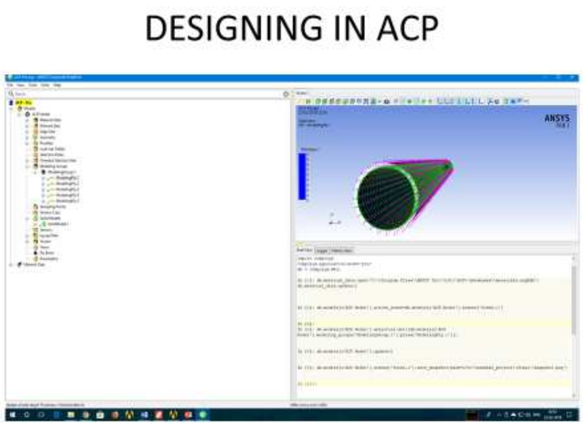

Figure 6: Designing in ACP

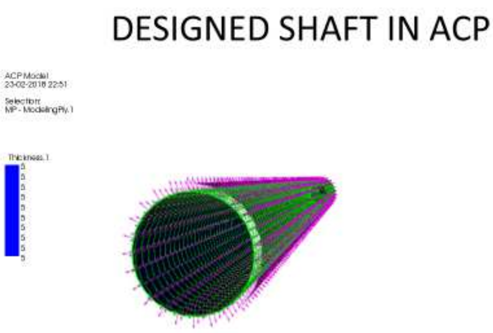

Figure 7: Designed Shaft in ACP

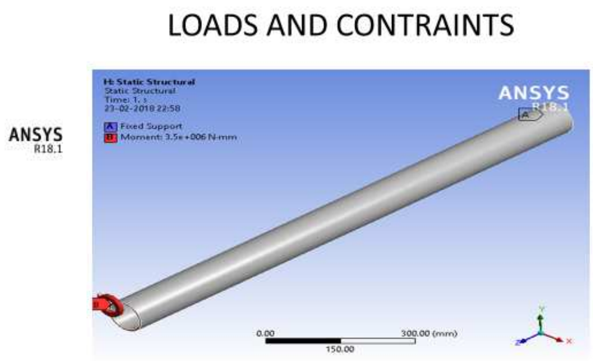

Figure 8: Loads and Constraints of E-Glass

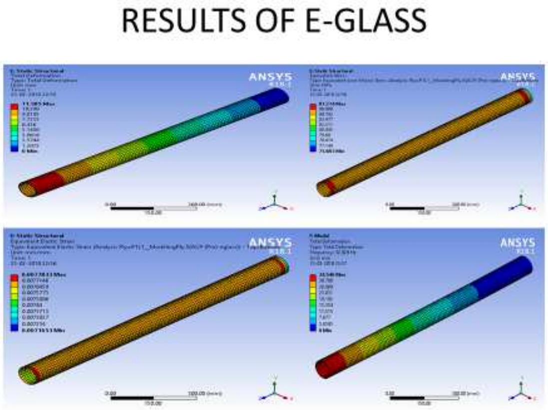

Figure 9: Results of E Glass

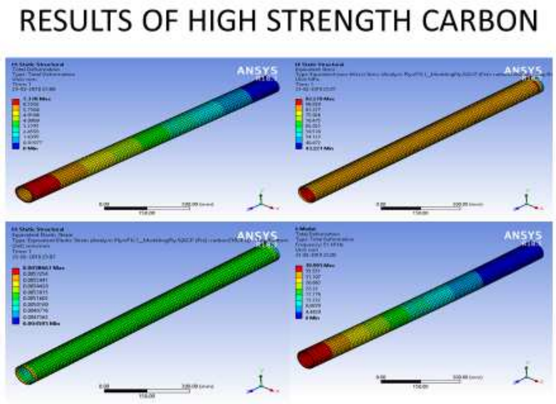

Figure 10: Results of High Strength Carbon

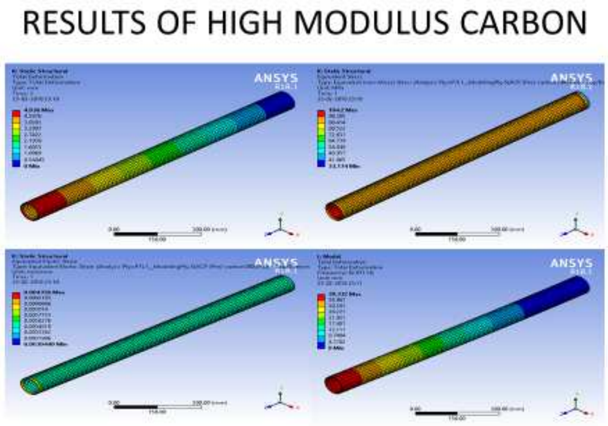

Figure 11: Results of High Modules Carbon

RESULTS

Table 5: Results

Material Name	Weight (Kg)	Total Deformation mm	Elastic Strain (mm/ mm)	Von Misses (MPa)	Frequencies (Hz)
Structural steel	13.101	1.0576	56703	113.2	1. 54.064 2. 324.19 3. 626.03 4. 853.65
E-glass/Epoxy	13.101	1.0576	0.0077833	87.274	1. 32.929 2. 197.73 3. 372.70 4. 520.16
High Strength Carbon	2.486	7.37	0.0058667	92.279	1. 51.14 2. 306.22 3. 535.9 4. 801.27
High Modulus carbon	2.57	4.936	0.004356	104.2	1. 62.81 2.375.86 3.643.05 4. 981.87

CONCLUSIONS

Based on the results it is concluded that High strength carbon with reduced weight shows deformationas 7.37 mm, elastic strain of 0.0058667 mm, von misses stress of 92.279 MPa at a frequency of (51.15, 306.22, 535.9, 801.27) is optimised when compared to other composite materials and conventional structural steel.

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